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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

PERFORMANCE CHARACTERISTICS OF A PAIR OF PROPELLERS FOR THE SEA FOX

by

James G. Peck

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SHIP PERFORMANCE DEPARTMENT

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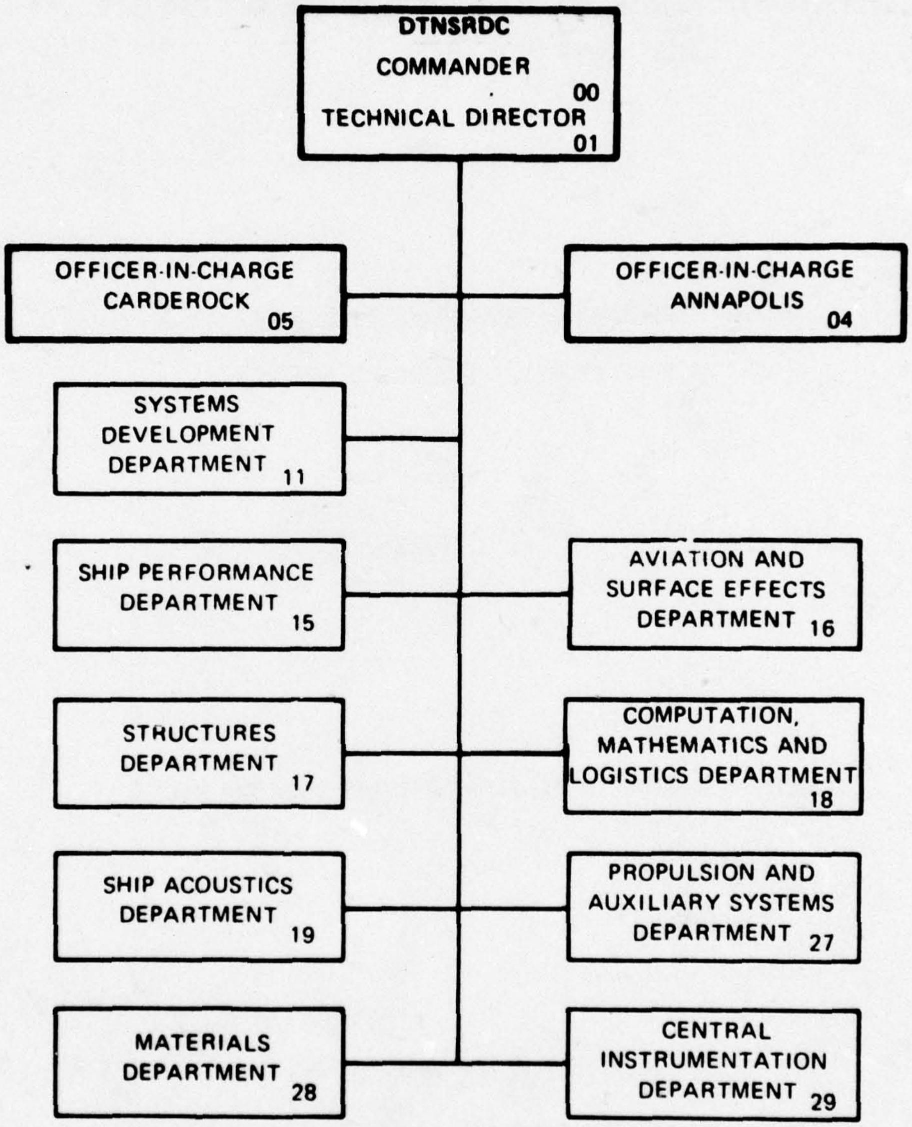

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Two 22 inch Newton Rader type full scale propellers were manufactured and tested for use during full scale trials on the 11 meter "Sea Fox". Open water tests were conducted and cavitating performance characteristics were obtained for these propellers over a range of cavitation numbers corresponding to full scale speeds from 9 to 45 knots. The propeller performance data and a table containing the principal propeller geometry information is presented in this report.

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NOTATION

		Dimensions
A_E	Expanded area of propeller blades $A_E = EAR\ (A_o)$	ft^2, m^2
A_o	Disc area of propeller $A_o = \frac{\pi D^2}{4}$	ft^2, m^2
A_P	Projected area of propeller blades $A_P = A_E\ (1.067-0.229\ P/D)$	ft^2, m^2
C	Blade section length	ft, m
$C_{0.7}$	Blade section at 0.7 radius	ft, m
D	Propeller diameter	ft, m
EAR	Expanded area ratio A_E/A_o	
g	Acceleration due to gravity	ft/sec^2, m/sec^2
h	Propeller submergence	ft, m
J	Advance coefficient $J = V/nD$	
K_T	Thrust coefficient $K_T = \frac{T}{\rho n^2 D^4}$	
K_T/J^2	Loading coefficient	
K_Q	Torque coefficient $K_Q = \frac{Q}{\rho n^2 D^5}$	
K_Q/J^3	Powering coefficient	
n	Propeller rotation speed	rev/sec, r/s
P	Propeller pitch	ft, m
P/D	Pitch-diameter ratio	
P_A	Atmospheric pressure	lb/ft^2, N/m^2
P_H	Static water pressure, $P_H = \rho gh$	lb/ft^2, N/m^2
P_V	Vapor pressure	lb/ft^2, N/m^2
T	Propeller thrust	lb, N

		Dimensions
Q	Propeller torque	lb/ft, N·m
Q_c	Torque load coefficient, $Q_c = \dfrac{2.55\ K_Q}{(J^2 + 4.84)(EAR)(1.067 - 0.229\ P/D)}$	
v	Velocity of boat	ft/sec, m/sec
$v_{0.7}$	Resultant velocity of water at 0.7 radius of propeller $v_{0.7}^2 = \dfrac{J^2 + 4.83}{J^2} v^2$	ft/sec, m/sec
η	Propeller open water efficiency, $\eta = \dfrac{K_T}{K_Q} \dfrac{J}{2\pi}$	
ρ	Mass density of water	$lb\text{-}sec^2/ft^4$, K_g/m^3
σ	Cavitation number, $\sigma = \dfrac{P_A + P_H - P_V}{\frac{1}{2} \rho v^2}$	
$\sigma_{0.7}$	Local cavitation number, $\sigma_{0.7} = \dfrac{P_A + P_H - P_V}{\frac{1}{2} \rho v_{0.7}^2}$	
τ	Thrust load coefficient, $\tau = \dfrac{T}{\frac{1}{2} \rho A_p v_{0.7}^2}$	

ABSTRACT

Two 22 inch Newton Rader type full scale propellers were manufactured and tested for use during full scale trials on the 11 meter "Sea Fox". Open water tests were conducted and cavitating performance characteristics were obtained for these propellers over a range of cavitation numbers corresponding to full scale speeds from 9 to 45 knots. The propeller performance data and a table containing the principal propeller geometry information is presented in this report.

ADMINISTRATIVE INFORMATION

This work was performed for the Naval Ship Engineering Center, Norfolk Division under Task Area S0414-SW001 and Project Element 63586N.

INTRODUCTION

The Naval Ship Engineering Center Norfolk Division (NAVSECNORDIV) requested that the David Taylor Naval Ship R&D Center (DTNSRDC) procure and characterize a pair of propellers for use during full scale trials of the "Sea Fox". This pair of propellers was manufactured for DTNSRDC as per NAVSEA drawing No. Seafox 101-5033153 by Michigan Wheel Co. The principal dimensions of these propellers are given in Table 1.

Open water characteristics were obtained on both right and left hand propellers. Cavitating performance characteristics were obtained on the right hand propeller only since open water test results indicated that the performance of the two propellers is essentially identical. Upon completion of the test program this pair of propellers was shipped to the boat construction site as per NAVSECNORDIV request.

EXPERIMENTAL PROCEDURE AND FACILITIES

Open water characteristics of the propellers were obtained in the deep water basin using the 35 HP dynamometer. Both propellers were characterized in open water over a range of speed coefficients (J) from zero velocity to zero thrust. The Reynolds number for the open-water tests ranged from 2.5×10^6 to 3.1×10^6.

Cavitation characteristics of the propellers were obtained in the 36" Variable Pressure Water Tunnel in uniform flow. Two water velocities, 25 fps and 30 fps were used to provide a range of cavitation numbers from 9.43 to 0.40. The cavitation numbers represent a range of full scale speeds from 9.4 to 45 knots. Reynolds number for the cavitation experiments ranged from 4.0×10^6 to 7.4×10^6.

PRESENTATION OF DATA AND DISCUSSION

The open water characteristics data of the propellers were reduced to the usual nondimensional coefficients of thrust and torque. The open water characteristics for both propellers are presented in Figure 1. The closeness of the coefficients for the left hand and right hand propellers indicate that they are very closely matched in both pitch and blade outline.

Cavitating performance characteristics were obtained for the right hand propeller for cavitation numbers ranging from 9.4 to 0.4. These data

were reduced to the usual nondimensional coefficients of torque, thrust, and efficiency. In addition to the normal coefficients the nondimensional coefficients of K_T/J^2, K_Q/J^3, Q_c, $\sigma_{0.7}$ and τ were calculated. Curves showing K_T, K_Q and η for constant values of σ are shown plotted against J in Figure 2. Tabulated values of J, K_T, K_Q, η, K_T/J^2, K_Q/J^3, Q_c, $\sigma_{0.7}$ and τ for all test conditions are provided in Table 2. Representative cavitation patterns for thrust loading coefficient (K_T/J^2) of 0.10 and 0.15 are shown in Figure 3.

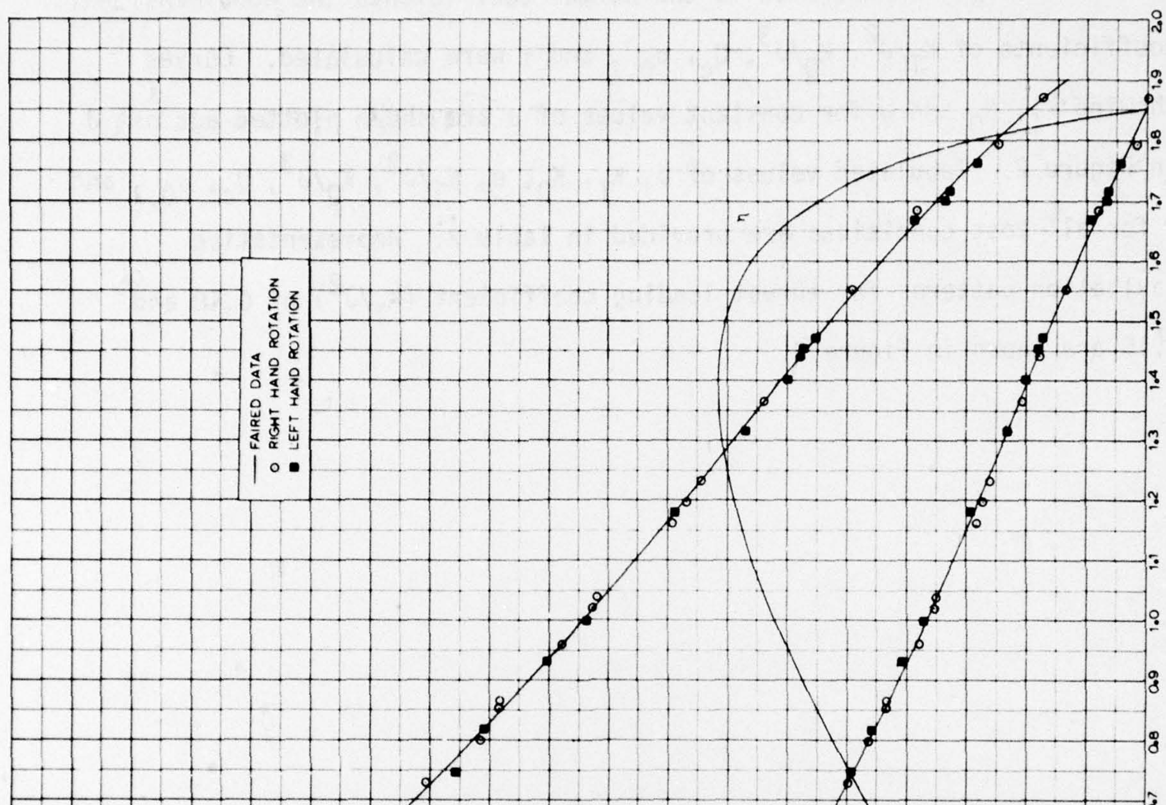

Figure 1 - Open Water Propeller Characteristics

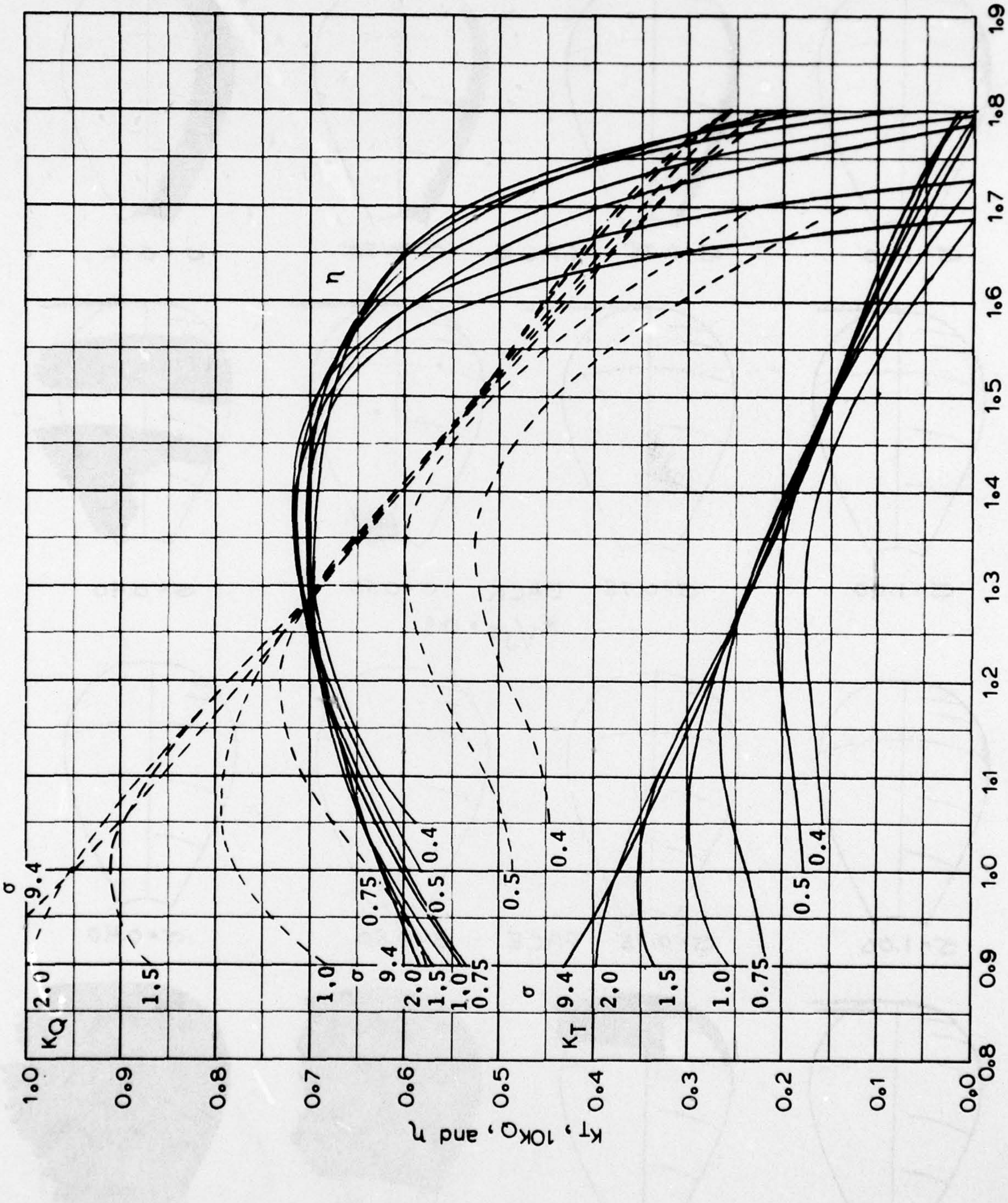

Figure 2 - Propeller Cavitation Performance Characteristics

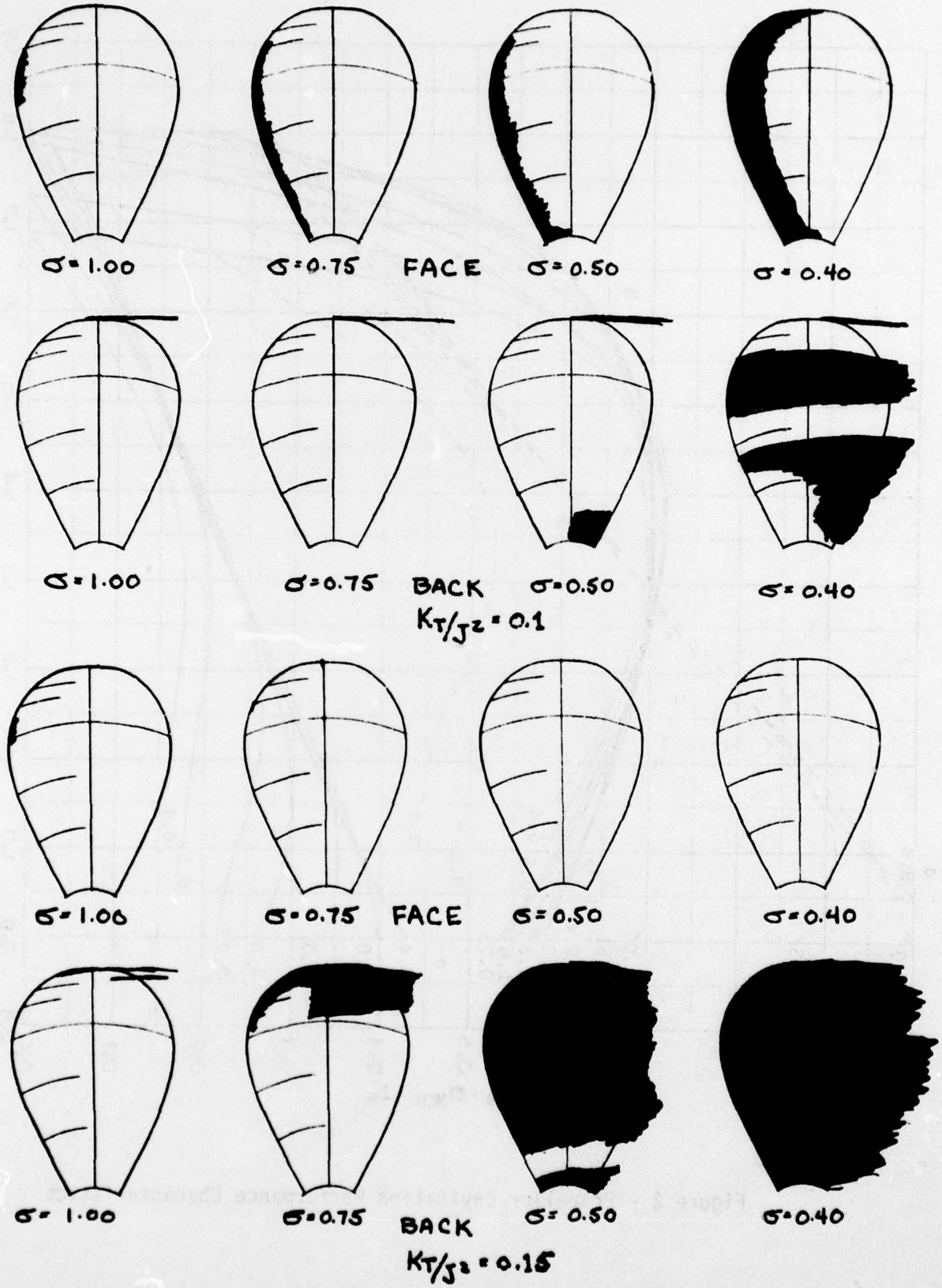

Figure 3 - Representative Sketches of Cavitation Patterns for Thrust Loading Coefficients of 0.10 and 0.15

TABLE 1 - PROPELLER GEOMETRY

No. of Blades	3
Diameter	22 in (558 mm)
Pitch	34 in (863 mm)
Pitch Ratio	1.545
Developed Area Ratio	0.719
Hub to Diameter Ratio	0.18

TABLE 2 - TABULATED VALUES OF PROPELLER CAVITATION PERFORMANCE CHARACTERISTICS

Cavitation No. = 9.43

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.9000	.4302	1.0541	.5846	.5311	.1446	.0814	1.3519	.8752
.9500	.4009	1.0009	.6056	.4443	.1167	.0760	1.4820	.8025
1.0000	.3734	.9509	.6250	.3734	.0951	.0710	1.6147	.7350
1.0500	.3475	.9036	.6426	.3152	.0781	.0663	1.7495	.6721
1.1000	.3228	.8583	.6585	.2668	.0645	.0619	1.8860	.6133
1.1500	.2993	.8148	.6724	.2263	.0536	.0576	2.0237	.5583
1.2000	.2768	.7724	.6843	.1922	.0447	.0536	2.1623	.5066
1.2500	.2550	.7310	.6939	.1632	.0374	.0498	2.3013	.4577
1.3000	.2337	.6900	.7008	.1383	.0314	.0461	2.4405	.4114
1.3500	.2129	.6492	.7045	.1168	.0264	.0425	2.5795	.3672
1.4000	.1922	.6083	.7042	.0981	.0222	.0390	2.7181	.3250
1.4500	.1717	.5670	.6988	.0817	.0186	.0356	2.8558	.2843
1.5000	.1511	.5252	.6867	.0671	.0156	.0323	2.9926	.2449
1.5500	.1302	.4826	.6656	.0542	.0130	.0291	3.1281	.2067
1.6000	.1090	.4392	.6320	.0426	.0107	.0259	3.2623	.1693
1.6500	.0873	.3948	.5806	.0321	.0088	.0228	3.3948	.1327
1.7000	.0650	.3494	.5031	.0225	.0071	.0197	3.5256	.0966
1.7500	.0419	.3029	.3853	.0137	.0057	.0167	3.6545	.0609
1.8000	.0180	.2553	.2019	.0056	.0044	.0138	3.7813	.0256

Cavitation No. = 2.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.9000	.3968	.9964	.5704	.4899	.1367	.0769	.2867	.8073
.9500	.3882	.9811	.5982	.4301	.1144	.0745	.3143	.7770
1.0000	.3733	.9539	.6228	.3733	.0954	.0712	.3425	.7348
1.0500	.3540	.9188	.6444	.3211	.0793	.0674	.3711	.6847
1.1000	.3317	.8761	.6628	.2741	.0658	.0631	.4000	.6301
1.1500	.3076	.8306	.6779	.2326	.0546	.0588	.4292	.5730
1.2000	.2829	.7834	.6897	.1965	.0453	.0544	.4586	.5178
1.2500	.2584	.7363	.6981	.1653	.0377	.0501	.4881	.4638
1.3000	.2346	.6902	.7032	.1388	.0314	.0461	.5176	.4129
1.3500	.2120	.6460	.7050	.1163	.0263	.0423	.5471	.3657
1.4000	.1907	.6040	.7034	.0973	.0220	.0387	.5765	.3223
1.4500	.1706	.5642	.6980	.0812	.0185	.0354	.6057	.2825
1.5000	.1516	.5262	.6879	.0674	.0156	.0324	.6347	.2458
1.5500	.1331	.4890	.6714	.0554	.0131	.0294	.6634	.2112
1.6000	.1143	.4514	.6450	.0447	.0110	.0266	.6919	.1776
1.6500	.0944	.4117	.6021	.0347	.0092	.0237	.7200	.1435
1.7000	.0721	.3679	.5304	.0250	.0075	.0208	.7477	.1072
1.7500	.0461	.3175	.4047	.0151	.0059	.0175	.7751	.0671
1.8000	.0140	.2576	.1649	.0046	.0044	.0139	.8020	.0211

Cavitation No. = 1.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.9000	.3358	.8696	.5531	.4145	.1193	.0671	.2150	.6831
.9500	.3519	.9034	.5889	.3899	.1054	.0686	.2357	.7063
1.0000	.3539	.9107	.6185	.3539	.0911	.0680	.2568	.6986
1.0500	.3453	.8975	.6429	.3132	.0775	.0659	.2783	.6679
1.1000	.3290	.8696	.6626	.2719	.0653	.0627	.3000	.6251
1.1500	.3077	.8311	.6777	.2327	.0546	.0588	.3219	.5739
1.2000	.2835	.7866	.6883	.1969	.0455	.0544	.3439	.5188
1.2500	.2581	.7392	.6948	.1652	.0378	.0503	.3661	.4636
1.3000	.2331	.6915	.6973	.1379	.0315	.0462	.3882	.4102
1.3500	.2092	.6456	.6964	.1148	.0262	.0422	.4103	.3609
1.4000	.1871	.6021	.6924	.0955	.0219	.0386	.4324	.3162
1.4500	.1669	.5620	.6855	.0794	.0184	.0353	.4543	.2764
1.5000	.1484	.5247	.6752	.0660	.0155	.0323	.4760	.2406
1.5500	.1309	.4895	.6598	.0545	.0131	.0295	.4976	.2070
1.6000	.1134	.4546	.6353	.0443	.0111	.0268	.5189	.1761
1.6500	.0942	.4170	.5934	.0346	.0093	.0240	.5400	.1432
1.7000	.0717	.3753	.5183	.0248	.0076	.0211	.5608	.1066
1.7500	.0434	.3223	.3754	.0142	.0060	.0178	.5813	.0632
1.8000	.0068	.2565	.0757	.0021	.0044	.0138	.6015	.0096

Cavitation No. = 1.0

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.9000	.2570	.6825	.5394	.3173	.0936	.0527	.1434	.5220
.9500	.2811	.7403	.5742	.3115	.0863	.0562	.1572	.5627
1.0000	.2944	.7756	.6041	.2944	.0776	.0579	.1712	.5794
1.0500	.2987	.7920	.6302	.2709	.0684	.0581	.1855	.5777
1.1000	.2956	.7927	.6529	.2443	.0596	.0571	.2000	.5616
1.1500	.2868	.7807	.6720	.2169	.0513	.0552	.2146	.5349
1.2000	.2735	.7587	.6886	.1900	.0439	.0527	.2293	.5007
1.2500	.2570	.7290	.7013	.1645	.0373	.0496	.2440	.4613
1.3000	.2381	.6936	.7102	.1409	.0316	.0463	.2588	.4191
1.3500	.2176	.6541	.7148	.1194	.0266	.0428	.2735	.3754
1.4000	.1961	.6118	.7143	.1001	.0223	.0392	.2882	.3315
1.4500	.1741	.5679	.7076	.0828	.0186	.0357	.3028	.2883
1.5000	.1517	.5229	.6927	.0674	.0155	.0322	.3173	.2459
1.5500	.1290	.4772	.6668	.0537	.0128	.0287	.3317	.2047
1.6000	.1050	.4309	.6250	.0413	.0105	.0254	.3459	.1643
1.6500	.0817	.3836	.5592	.0300	.0085	.0221	.3600	.1242
1.7000	.0563	.3348	.4548	.0195	.0068	.0189	.3739	.0837
1.7500	.0288	.2835	.2827	.0094	.0053	.0156	.3875	.0419
1.8000	-.0017	.2284	-.0215	-.0005	.0039	.0123	.4010	-.0024

Cavitation No. = 0.75

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
.9000	.2151	.5766	.5343	.2655	.0791	.0445	.1075	.4375
.9500	.2254	.5997	.5683	.2497	.0699	.0455	.1179	.4511
1.0000	.2393	.6372	.5976	.2393	.0637	.0476	.1284	.4709
1.0500	.2523	.6763	.6234	.2288	.0584	.0496	.1391	.4880
1.1000	.2615	.7080	.6466	.2161	.0532	.0510	.1500	.4968
1.1500	.2650	.7269	.6673	.2004	.0478	.0514	.1610	.4944
1.2000	.2622	.7306	.6855	.1821	.0423	.0507	.1720	.4800
1.2500	.2531	.7188	.7004	.1620	.0368	.0490	.1830	.4544
1.3000	.2383	.6932	.7112	.1410	.0316	.0463	.1941	.4195
1.3500	.2190	.6567	.7165	.1202	.0267	.0430	.2052	.3778
1.4000	.1965	.6126	.7146	.1002	.0223	.0393	.2162	.3321
1.4500	.1721	.5648	.7034	.0819	.0185	.0355	.2271	.2850
1.5000	.1472	.5163	.6805	.0654	.0153	.0318	.2380	.2386
1.5500	.1224	.4694	.6433	.0509	.0126	.0283	.2488	.1943
1.6000	.0982	.4249	.5884	.0383	.0104	.0250	.2595	.1525
1.6500	.0740	.3812	.5097	.0272	.0085	.0220	.2700	.1125
1.7000	.0485	.3343	.3922	.0168	.0068	.0189	.2804	.0721
1.7500	.0190	.2770	.1914	.0062	.0052	.0153	.2907	.0277
1.8000	-.0182	.1982	-.2629	-.0056	.0034	.0107	.3007	-.0259

Cavitation No. = 0.5

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
1.0000	.1778	.4866	.5815	.1778	.0487	.0363	.0856	.3499
1.0500	.1806	.4940	.6109	.1638	.0427	.0362	.0920	.3493
1.1000	.1872	.5144	.6372	.1547	.0386	.0371	.1000	.3557
1.1500	.1950	.5407	.6602	.1475	.0356	.0383	.1073	.3638
1.2000	.2017	.5666	.6800	.1401	.0328	.0393	.1146	.3693
1.2500	.2056	.5871	.6966	.1316	.0301	.0400	.1220	.3690
1.3000	.2051	.5981	.7094	.1213	.0272	.0399	.1294	.3610
1.3500	.1993	.5968	.7176	.1094	.0243	.0391	.1368	.3439
1.4000	.1878	.5815	.7196	.0958	.0212	.0373	.1441	.3174
1.4500	.1703	.5513	.7129	.0810	.0181	.0346	.1516	.2820
1.5000	.1472	.5064	.6935	.0654	.0150	.0312	.1587	.2387
1.5500	.1193	.4495	.6547	.0497	.0121	.0271	.1659	.1893
1.6000	.0876	.3820	.5863	.0342	.0093	.0225	.1730	.1361
1.6500	.0539	.3079	.4596	.0198	.0068	.0178	.1800	.0819
1.7000	.0200	.2320	.2329	.0069	.0047	.0131	.1869	.0297

Cavitation No. = 0.4

J	KTOUT	10KQOUT	EFFIC	KT/J2	KQ/J3	QC	SIGMA7	TAUC
1.0500	.1574	.4460	.5898	.1428	.0385	.0327	.0742	.3045
1.1000	.1610	.4513	.6246	.1331	.0339	.0325	.0808	.3050
1.1500	.1668	.4686	.6516	.1262	.0308	.0332	.0858	.3112
1.2000	.1726	.4905	.6720	.1198	.0284	.0341	.0917	.3159
1.2500	.1763	.5104	.6872	.1128	.0261	.0348	.0976	.3165
1.3000	.1765	.5233	.6979	.1044	.0238	.0349	.1035	.3107
1.3500	.1720	.5250	.7037	.0944	.0213	.0344	.1094	.2967
1.4000	.1619	.5128	.7034	.0826	.0187	.0329	.1153	.2737
1.4500	.1459	.4851	.6942	.0694	.0159	.0305	.1211	.2416
1.5000	.1240	.4412	.6708	.0551	.0131	.0271	.1269	.2010
1.5500	.0966	.3820	.6225	.0401	.0103	.0230	.1327	.1530
1.6000	.0639	.3092	.5263	.0250	.0075	.0182	.1384	.0993
1.6500	.0276	.2261	.3218	.0101	.0050	.0130	.1440	.0420
1.7000	-.0110	.1367	-.2173	-.0038	.0028	.0077	.1495	-.0163

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

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AD-A048 383 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
PERFORMANCE CHARACTERISTICS OF A PAIR OF PROPELLERS FOR THE SEA--ETC(U)
DEC 77 J G PECK
UNCLASSIFIED SPD-806-01 NL

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SUPPLEMENTARY
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INFORMATION

ERRATA SHEET

These corrections should be made to DTNSRDC report SPD-806-01, "Performance, Characteristics of a Pair of Propellers for the SEA FOX," by James G. Peck, December 1977.

Add to Table 1, page 7:

Expanded Area Ratio 0.82

Replace TAUC columns in Table 2, page 8 with these values:

Sigma = 9.430		Sigma = 2.0		Sigma = 1.5	
J	TAUC	J	TAUC	J	TAUC
.9000	.3315	.9000	.3058	.9000	.2588
.9500	.3040	.9500	.2943	.9500	.2668
1.0000	.2784	1.0000	.2784	1.0000	.2639
1.0500	.2546	1.0500	.2594	1.0500	.2530
1.1000	.2323	1.1000	.2387	1.1000	.2368
1.1500	.2115	1.1500	.2174	1.1500	.2174
1.2000	.1919	1.2000	.1962	1.2000	.1966
1.2500	.1734	1.2500	.1757	1.2500	.1756
1.3000	.1558	1.3000	.1564	1.3000	.1554
1.3500	.1391	1.3500	.1385	1.3500	.1367
1.4000	.1231	1.4000	.1221	1.4000	.1198
1.4500	.1077	1.4500	.1070	1.4500	.1047
1.5000	.0928	1.5000	.0931	1.5000	.0912
1.5500	.0783	1.5500	.0800	1.5500	.0787
1.6000	.0641	1.6000	.0673	1.6000	.0667
1.6500	.0503	1.6500	.0543	1.6500	.0543
1.7000	.0366	1.7000	.0406	1.7000	.0404
1.7500	.0231	1.7500	.0254	1.7500	.0239
1.8000	.0097	1.8000	.0080	1.8000	.0037

ERRATA SHEET (Cont.)

Sigma = 1.0

J	TAUC
.9000	.1980
.9500	.2132
1.0000	.2195
1.0500	.2188
1.1000	.2128
1.1500	.2027
1.2000	.1897
1.2500	.1748
1.3000	.1587
1.3500	.1422
1.4000	.1256
1.4500	.1092
1.5000	.0932
1.5500	.0775
1.6000	.0622
1.6500	.0470
1.7000	.0317
1.7500	.0159
1.8000	-.0009

Sigma = .75

J	TAUC
.9000	.1657
.9500	.1709
1.0000	.1784
1.0500	.1849
1.1000	.1882
1.1500	.1873
1.2000	.1818
1.2500	.1721
1.3000	.1589
1.3500	.1431
1.4000	.1258
1.4500	.1080
1.5000	.0904
1.5500	.0736
1.6000	.0578
1.6500	.0426
1.7000	.0273
1.7500	.0105
1.8000	-.0098

Sigma = .50

J	TAUC
1.0000	.1326
1.0500	.1323
1.1000	.1348
1.1500	.1378
1.2000	.1399
1.2500	.1398
1.3000	.1367
1.3500	.1303
1.4000	.1202
1.4500	.1068
1.5000	.0904
1.5500	.0717
1.6000	.0516
1.6500	.0310
1.7000	.0113

Sigma = .40

J	TAUC
1.0500	.1153
1.1000	.1159
1.1500	.1179
1.2000	.1197
1.2500	.1199
1.3000	.1177
1.3500	.1124
1.4000	.1037
1.4500	.0915
1.5000	.0761
1.5500	.0580
1.6000	.0376
1.6500	.0159
1.7000	-.0062